Overview
ATV - Automated Transport Vehicle
sEMG - Surface Electromyography
OpenCV - Open Source Computer Vision

Key Words - Automation, robotics, disability assistance, infrared user tracking

People with disabilities need a device to more easily transport their possessions. The goal of this project is to create an ATV which can independently carry cargo, reducing bodily strain on the user. The ATV will be able to navigate through difficult terrain and follow a user via an onboard infrared camera. It will have an alternate control scheme, which takes input from filtered sEMG signals obtained from the user. An onboard computer will perform biosignal analysis, and allow for motor control of the robot using these processed signals.

Intellectual Merit
This Small Business Innovation Research Phase I project implements qualities from various disciplines, including computer science, mechanical engineering, biomedical engineering, and systems engineering. The first technical challenge will be the construction of the ATV. In order to fulfill size, weight, portability and mobility requirements, the ATV will be stabilized by a Rocker-Bogie mechanism similar to that of the Mars rovers. This will provide more freedom of movement, and let the ATV drive over simple curbs and small steps. The cargo compartment will remain relatively flat with the use of a differential gear system. User tracking will be accomplished using an infrared camera attached to an onboard computer. The infrared camera is capable of providing a stream of pictures at a rate of nine pictures a second. These pictures are each 80 by 60 pixels, and contain enough data encoded in infrared intensity values to track a user. The ATV's computerized control system will analyze these infrared images while simultaneously providing navigational instructions to the ATV's motorized wheels. OpenCV will be the initial framework used to parse image data, and it's multi-platform availability can provide flexibility for this project should a platform/operating system change become necessary. The biosignal acquisition will implement circuit-level filtering and amplification. Signals will pass through an Analog-to-Digital converter. The signals will be processed and converted to motor commands which will then travel wirelessly to the ATV's onboard computer. The computer will override automated control when receiving biosignal inputs, and allow for motor control using sEMG sensors.

Broader Impact

Multiple members participating in this project have undergone major surgeries, and suffered mobility restrictions as a result. A need exists to carry large amounts of cargo without straining one's arms or legs. Other devices exist which provide some combination of user tracking, multi-terrain capabilities, ease-of-use, and simplicity. However, no device currently exists which fulfills all of the previous qualifications. This research project will create such a device, and provide a method of cargo carrying for handicapped individuals.

Overview

Key Words - Automation, robotics, disability assistance, infrared user tracking

The goal of this project is to create an automated transport vehicle (ATV) which can independently carry cargo, thereby reducing bodily strain on the user. A reduction of bodily strain would greatly help people with disabilities, since this system will easily transport their heavy possessions. The ATV will be able to navigate through difficult terrain and follow a user via an onboard camera.

Intellectual Merit

This Small Business Innovation Research Phase I project implements qualities from various disciplines, including computer science, mechanical engineering, biomedical engineering, and systems engineering. The first technical challenge will be the construction of the ATV. In order to fulfill size, weight, portability and mobility requirements, the ATV will be stabilized by a Rocker-Bogie mechanism similar to that used by the Mars rovers. This will provide more freedom of movement, and let the ATV drive over curbs and small steps. The cargo compartment will remain relatively flat with the use of a differential gear system. This ATV leverages existing technologies, but combines them in a compact profile and with a simple-to-use interface that has not been seen before in other devices. User tracking will be accomplished with an infrared camera, and the produced stream of infrared pictures will be analyzed before providing navigational instructions to the ATV's motorized wheels. Infrared imagery has historically been reserved for military technologies and challenges, providing a means for weapon systems to locate targets in varied environments. Infrared's applicability in target acquisition and tracking is undeniable, but its usage in consumer-grade computer vision systems is surprisingly limited. This project hopes to fill in that void. The open-source toolset, OpenCV, will be used to parse image data, and its multi-platform availability can provide flexibility for this project should a platform/operating system change become necessary.

Broader Impact

While the original intention of this project was to help disabled individuals carry heavy cargo without strain on the arms and legs, other use cases for this project exist. Elderly individuals and individuals with temporary handicaps would benefit greatly from this technology. Similar systems are in development to increase productivity at retail stores, malls, other marketplaces. An automated system that carries both heavy items and a large quantity of items around a store would benefit both customers and employees. This project expands upon extensive research done in the field of computer vision, user-tracking and robotics. However, there is little previous research in computer vision applications using infrared imagery, and this project hopes to build a foundation for this field of study.

Elevator Pitch

Times when one is required to carry large items, heavy items, or just too many items are frequent. A system that eliminates such a tedious chore would have many potential use cases. The elderly, handicapped, temporarily disabled, and customers and employees of large retail stores can reduce incredible amounts of bodily strain by letting an automated system transport heavy loads. Creating a system that can both carry heavy objects and automate its movement is the ultimate end goal for this project. Using technologies typically reserved for military applications, this automated transport vehicle (ATV) will be able to follow a user through various terrain, over obstacles like curbs and stairs, and keep its cargo area safe and flat. An onboard computer system will be able to identify and follow a designated target within the field of view of the attached Forward Looking Infrared (FLIR) camera.

Similar technologies exist or are in development. Systems like the Leo by SITA perform customer check-ins and have pioneered automated baggage reception and transportation at airports. Starship Technologies has created a robot that operates on a programmed schedule, can traverse crowded areas, and automate the laborious process of picking up groceries and other necessities. Our project's goal lies somewhere between these two systems--the ATV will help with deliveries, can navigate through urban, suburban, and rural terrain, and carry heavy loads. However, no previous projects have provided a reliable method for user identification and tracking. They have been operating in previously known and mapped out environments, while this system will always be actively analyzing its environment, and not relying on existing data. Implementing techniques from the realms of computer science, mechanical engineering, biomedical engineering, and systems engineering, this project will present numerous challenges. In order to fulfill size, weight, portability and mobility requirements, the ATV will be stabilized by a Rocker-Bogie mechanism similar to that used by the Mars rovers. A differential gear system will stabilize the cargo compartment, ensuring that the user's belongings remain unscathed while being transported. This project will begin a discussion about image analysis and computer vision using FLIR cameras, and will add to the extensive list of projects accomplished using the open-source vision software, OpenCV. The ATV has great effort-conserving potential, and knowledge gained from its development can be used by future computer vision systems primarily concerned with the identification of humans.

The Commercial Opportunity

The target audience for this Automated Transport Vehicle is quite diverse and the potential avenues for monetization are numerous. This ATV is intended for individuals that are physically handicapped, temporarily handicapped, or non-disabled individuals trying to minimize the negative effects of daily lifting. This system will be suited for usage in various settings, and can become a valuable post-surgery recovery utility. With ample carrying capability condensed into a compact frame, this system can be stored in one's domicile and become an integral tool for reducing the intensity of a morning commute. This system can become as ubiquitous as crutches or slings in the road to surgical recovery, and will create profits once consumers and insurance companies realize the benefits of an ATV.

In recent years, the usage of robotics to assist with daily tasks has been increasing. The success of the Roomba has demonstrated that customers are willing to purchase high-end electronic systems to automate difficult tasks. The Roomba is still netting a profit for its parent company, iRobot, over a decade since its inception in 2002. Technology and robotics are becoming integrated into the daily lives of millions of people, and the ATV would easily take advantage of this trend and become a flagship utility. Twenty pounds may not sound like a large amount of weight, but daily lifting of twenty pound items can have devastating effects on one's back and body. Stress on the joints is often difficult to identify until it is too late for recovery. Many doctors recommend against the lifting of twenty pound objects while pregnant, as it can seriously increase the probability of a miscarriage.[1] Pregnant women, construction workers, mailmen, nurses, students, and many other individuals would benefit from having a mobile storage unit capable of following an individual. With a reasonable market-entry price of $300, this transport system would have many potential user bases. The ATV can become successful with accompanying advertisement campaigns and positive reviews travelling over the Internet or through word-of-mouth.

Our ideal commercialization approach will begin with an aggressive marketing campaign conveying the diverse groups of people able to benefit from the purchase of an ATV. The marketing campaign would highlight the health and economic benefits associated with the ATV. This product has direct, previously mentioned health-related benefits. By reducing the load an individual must carry, the ATV can both prevent injury and help expedite the recovery process for previous injuries. These health-related benefits can be translated into economic benefits, as time spent injured can negatively affect one's ability to earn income. For most of the workforce, time spent injured is time spent unable to work and earn a wage. However, with an ATV and the ability to easily transport one's required work materials, it becomes possible for a victim of health issues to recover and get back to work faster. The ATV can also be used to increase the work efficiency of numerous occupations. A construction worker can load up a set of tools and machinery on an ATV, easily walk around the workplace, and put his effort towards actual construction tasks instead of lugging around materials. A nurse or doctor can fill an ATV with patient records and medical instruments, and spend more time assisting patients rather than

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[1] Occupational lifting of heavy loads and preterm birth: a study within the Danish National Birth Cohort, Nov 2013.

trekking around the hospital while tracking down records. The technology and research obtained from pursuing this project can be put towards other related uses, such as automating the movement of shopping carts at a large retail or grocery store. A store that eliminates the task of pushing around a heavy cart would surely attract more customers. These customers would feel comfortable purchasing more items than when using a manual push cart, offsetting the store chain's initial investment in our technology and leading to significant rewards in the long run.

As excited as our team is to bring the ATV to the mass market, there are some possible risks to be encountered before reaching market penetration. The biggest risk is a market with competing Automated Transport Vehicles reducing the potential profitability of this product. There are similar products in various stages of development: some in early phases of development, few in prototyping and revision phases, and even fewer currently testing out the market. These are products that have autonomous cargo-carrying capabilities, but none so far combine that with individual user-tracking capabilities in dynamic environments. At some major international airports, robots are being implemented as mobile check-in locations, performing the printing of boarding passes and autonomously carrying luggage to proper luggage receptacles.[2] Other robotic systems are attempting the "last mile" of the delivery problem, which occurs when a shipment must reach a customer's doorstep. This require visual and sensory analysis of dynamic locations to ensure the safe delivery of cargo.[3] There is little work being done to create a personal cargo carrier that focuses on the tracking of an individual, is not reliant upon previously-gathered map data, and can analyze and reroute itself based on encountered obstacles. This ATV will begin research into a new field of human-robot interactions and autonomous cargo carrying, and may encounter new regulations as a result.

Technological capabilities have recently reached a point where autonomous robots are able to safely navigate urban environments. As a result, laws and regulations have been forced to keep up with such technological trends. The recent Personal Delivery Device Act of 2016 contains a small number of regulations for a new class of Personal Delivery Devices that our ATV falls under.[4] This act is brief, but outlines a few safety mandates making sure that this class of devices will not disrupt the flow of pedestrians, bicyclists, or car traffic. It also must have a manual override and alerting system in case of error. The ATV will conform to this Act with little modification to our current plans, but there lies the possibility of newer and more comprehensive legislation in the near future. The ATV, while technically autonomous, is always tracking a human "mentor". This mentor serves as a target to follow, but also ensures that the robot is following proper traffic safety and in conformity with any future legislation.

Societal Impact

The amount of cargo one can easily carry in a vehicle is often a limiting factor. By expanding the amount and weight of things an individual can easily carry, the ATV has great potential in improving efficiency in the workplace and improving the health of customers. If used widely, the arduous task of lugging around a backpack or suitcase could become a remnant of

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[2] https://www.sita.aero/innovation/sita-lab/leo-sitas-baggage-robot
[3] https://www.starship.xyz/
[4] https://trackbill.com/bill/dc-b673-personal-delivery-device-act-of-2016/1287806/

the past. Of the nearly 80% of Americans who suffer from lower back pain, those who purchase an ATV would enjoy a reduction in pain after removing the transportation of heavy objects from their daily routines. Those recovering from injury and are able to transport themselves would receive a huge productivity boost with a new method of transporting their work equipment, groceries, or other necessary cargo. However, with increased reliance on robotics to assist in daily tasks, some negative consequences arise.

The environmental impact of widespread use of the ATV and other similar Personal Delivery Devices is small, but still present. The ATV's construction promotes power efficiency in order to prolong battery life, but as with any motorized device, it consumes a considerable amount of power. Widespread usage of this ATV might also bring safety concerns to the forefront. A large part of this project is devoted to helping customers recover from injuries, and creating a product that possesses the ability to cause more injuries is counterintuitive. The ATV will weigh less than 30 pounds and travel less than five miles an hour. These physical restraints keep the ATV within a small enough frame to cause minimal disturbance to a pedestrian upon contact if an occurrence happens where all object-avoidance capabilities, user-intervention, and manual control fail. This element of safety is extended to the physical construction of the system as well.

The ATV will have a compartment that opens and closes slowly, minimizing the potential risk to children. The inner components, wires, and sensors will be contained within the skeleton of the device, ensuring children will not be harmed by this device and providing limited waterproofness. The final version of the ATV will be designed to be simple to operate in order to accommodate our target audiences. It is anticipated that a large portion of the user base will be disabled of some sort, whether that means missing the use of an arm, or leg, or other bodily feature. As such, the ATV will be outfitted with simple user controls that require minimal human configuration and intervention. With numerous positive capabilities, we anticipate this device being put to good uses. Unfortunately, a few negative aspects have required planning in order to remediate.

As with any mobile storage area containing possibly expensive devices, theft poses a significant problem. In light of the potential for theft, the ATV will have an optional locking mechanism, ensuring that the cargo compartment can only be opened with consent of the owner. So far, the ATV does not have any protective measures to prevent theft of the whole system itself. We hope that the size and weight of the system combined with the fact that is always moving is enough of a deterrence factor. If this ends up being a prevalent, recurring issue, anti-theft countermeasures can be added to existing ATVs via a software update, and new models can have an extra anti-theft module built in. This anti-theft component is not included in the initial model, as we feel that this would be an inefficient usage of battery power and resources, as these resources would be better spent on robot navigation functions.

Once the ATV hits the market and becomes more commonly utilized, regulation may need to be implemented. As mentioned earlier, the Personal Delivery Device Act of 2016 is an early example of the type of legislation that can be expected. These expected regulation efforts will mostly be related to ensuring the safety of users and the public, and may be comparable to currently evolving drone regulations. Drones are not held accountable for causing injury or flying into restricted airspace. Instead, the pilots are held accountable, and the ATV will adhere to a similar policy. Therefore, an owner of an ATV will be held responsible for the proper usage of his system and any infractions that occur from user error or operation in an unlawful area. Legislation for the ATV is a welcome aspect of product creation, and we do not anticipate any potential requirements that would require complex modification in order to comply. We look forward to ensuring our product is lawful and helpful, and has far-reaching benefits.